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DESCRIPTION

AN ADJUSTMENT METHOD OF A DISPLAY DEVICE AND DISPLAY DEVICE

Technical Field

5 The present invention relates to an adjustment method of a display device particularly having LEDs (Light-Emitting Diode) of three primary colors, R, G, B, and the display device.

10 Background Art

Conventionally, as a liquid crystal display device using LEDs of three primary colors, R(red)-G(green)-B(blue), liquid crystal display devices of field sequential system (hereinafter, referred to as 15 an FS system) have been implemented, for example, as disclosed in JP 2000-241811. In the FS-system liquid crystal display device, three-color LEDs are provided on the back surface of a liquid crystal shutter, each of the LEDs is sequentially lighted at high speed while 20 opening and closing the liquid crystal shutter at each pixel position to be synchronized with lighting of the LEDs, and thereby, a desired color can be displayed at each pixel position.

For example, in the case of displaying red, the 25 liquid crystal shutter is opened during a period of time a red LED emits light, and then closed during a period of time a green LED emits light and a period of time a

blue LED emits light. The case of displaying green or blue is the same, and the liquid crystal shutter is opened only during a period of time the LED of desired color emits light, and closed during periods of time the other 5 LEDs emit light.

Further, opening the liquid crystal shutter for periods during which red and green LEDs emit light enables Y (Yellow) to be displayed, opening the liquid crystal shutter for periods during which red and blue LEDs emit 10 light enables M (Magenta) to be displayed, opening the liquid crystal shutter for periods during which green and blue LEDs emit light enables C (Cyan) to be displayed, and opening the liquid crystal shutter for all the periods during which red, green and blue LEDs emit light enables 15 W (White) to be displayed.

In such an FS system, by lighting three-color LEDs sequentially at speed higher than human visual reaction speed, color display is implemented by additive color process. Then, adopting the FS system eliminates the 20 need of color filter, and enables sharpened color display to be performed.

However, it is inevitable that an LED of each of colors, R, G, B, has a few fluctuations in emission wavelength with products due to fluctuations in products 25 when manufactured, and as a result, complicated operation is required to achieve the desired white balance. For example, a method is used of making a fine adjustment

to resistance or the like of an LED of each color assembled into a display device, or of selecting an LED of each color such that the desired white balance is achieved, but there arises a problem that the operation requires 5 some effort.

#### Disclosure of Invention

It is a principal object of the present invention to provide an adjustment method of a display device and 10 display device enabling a white balance adjustment to be made with ease even when there are fluctuations in emission characteristics of LEDs. It is a further object of the present invention to reduce current consumption when such a white balance adjustment is made.

15 The object is achieved by controlling emission of an LED of each color during a unit emission period using a PWM signal, and storing in storage a duty ratio of the PWM signal for the LED of each color such that the white balance falls within an allowable range. Further, rough 20 luminance adjustment is first made by storing a minimum voltage value for each color when a luminance higher than a target is obtained in a state where the duty ratio is maximum, and fine luminance adjustment is then made by varying the duty ratio of the PWM signal while applying 25 the stored applied voltage of fixed value, whereby current consumption can be reduced, in addition to the fact that the white balance is adjusted with excellence.

#### Brief Description of Drawings

FIG.1 is a block diagram illustrating a configuration of an LED driving device of an embodiment;

5 FIG.2 is a diagram showing minimum voltage values required to obtain a desired luminance in an LED of each color;

FIG.3 is a block diagram illustrating a configuration of a driving voltage setting device according to the embodiment;

10 FIG.4 is a flowchart to explain processing for setting an applied voltage and a duty ratio in the driving voltage setting device;

FIG.5 is a flowchart to explain processing for setting a duty ratio to obtain the desired white balance;

15 FIG.6 is a chromaticity spatial diagram to explain the processing for setting a duty ratio to obtain the desired white balance; and

FIG.7 is a waveform diagram to explain the operation of the LED driving device.

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#### Best Mode for Carrying Out the Invention

An embodiment of the present invention will specifically be described below with reference to accompanying drawings.

25 In FIG.1, "10" denotes an LED driving device as a whole. LED driving device 10 is provided in a liquid crystal display device, and drives LEDs of three colors,

R, G and B, provided on the back face of a liquid crystal panel. Further, this embodiment describes the case of applying the present invention to a liquid crystal display device of field sequential system, as an example.

5 LED driving device 10 has R (red) applied voltage storage register 11, G (green) applied voltage storage register 12 and B (blue) applied voltage storage register 13. Each of the registers 11, 12 and 13 stores voltage values to apply to the R, G, or B LED, respectively. Each 10 of the registers 11, 12 and 13 is connected to storage value setting bus 14, and applied voltage values for the LED of each color are stored in each of the registers 11, 12 and 13 via storage value setting bus 14 when a product of LED driving device 10 is shipped.

15 The applied voltage value for the LED of each color output from each of the registers 11, 12 and 13 is input to register selecting circuit 15. Register selecting circuit 15 further receives as its inputs a red-LED emission timing signal TR, green-LED emission timing 20 signal TG, and blue-LED emission timing signal TB, and based on the emission timing signal, selects either the applied voltage value for R, G or B to output.

For example, when the red-LED emission timing signal TR has a logic value of "1", and each of the green-LED 25 emission timing signal TG and blue-LED emission timing signal TB has a logic value of "0", the circuit 15 selects the applied voltage value stored in R applied voltage

storage register 11. In the case of this embodiment, since display is performed in the field sequential system, for example, when the field frequency is assumed to be 65Hz, the LED of each color is lighted sequentially with 5 the three-time frequency, 195Hz. In other words, register selecting circuit 15 selects and outputs voltage values stored in R applied voltage storage register 11, G applied voltage storage register 12 and B applied voltage storage register 13 in turn at intervals of about 5mS.

10 The applied voltage value selected by register selecting circuit 15 is converted into an analog value by digital analog (DA) converting circuit 17 in applied voltage forming circuit 16, and then output to voltage varying circuit 18. Voltage varying section 18 converts 15 a voltage generated in power supply voltage generating circuit 19 into a voltage corresponding to an analog value input from digital analog converting circuit 17, and supplies the voltage to LED unit 20.

Thus, LED driving device 10 has the registers 11, 20 12 and 13 that store voltage values to apply to LEDs of respective colors, and converts a voltage generated in power supply voltage generating circuit 19 into a value stored in the register 11, 12 or 13 to supply to a corresponding one of the LEDs. By this means, it is 25 possible to reduce power consumption as compared with the case of applying the same voltage to the LED of each color.

FIG.2 shows minimum applied voltage values (hereinafter referred to as minimum emission voltages) required to obtain a desired luminance in an LED of each color. As can be seen from the figure, minimum emission voltages of the green LED and blue LED are almost the same, while minimum emission voltages of the red LED are 5 lower than those minimum emission voltages.

Applied voltage storage registers 11, 12 and 13 of LED driving device 10 store minimum emission voltage 10 values of the LEDs of respective colors. Among the stored minimum emission voltage values, values of the red LED are actually lower than values of the green LED and blue LED. In other words, it is possible to apply a minimum voltage required for each of the LEDs, and it is thus 15 possible to reduce current consumption.

Further, as can be seen from FIG.2, even in the LED of each color, fluctuations arise in minimum emission voltage. For example, the minimum emission voltage fluctuates in a range of 1.75V to 2.45V in the red LED, 20 while fluctuating in a range of 2.9V to 3.9V in the green LED and blue LED. The fluctuations in minimum emission voltage are due to fluctuations in individual product caused by LED manufacturing.

In this embodiment, not only setting applied voltages for the red LED lower than applied voltages for the green and blue LEDs, applied voltages in consideration 25 of fluctuations in minimum emission voltage among

individual products are stored in the registers 11, 12 and 13 for respective colors. It is thereby possible to obtain a desired luminance of the LED of each color while reducing power consumption. Applied voltage 5 values are stored in the registers 11, 12 and 13 for respective colors via storage value setting bus 14, as described later.

Referring to FIG.1 again, a configuration of LED driving device 10 will be described below. LED driving 10 device 10 has R duty ratio storage register 21, G duty ratio storage register 22 and B duty ratio storage register 23. Each of the registers 21, 22 and 23 stores duty ratio data of PWM signal to perform PWM control on the LED of each color, R, G, or B, respectively. Each of the 15 registers 21, 22 and 23 is connected to storage value setting bus 14, and the duty ratio data for the LED of each color is stored in each of the registers 21, 22 and 23 via storage value setting bus 14 when the product of LED driving device 10 is shipped.

20 The duty ratio data for the LED of each color output from each of the registers 21, 22 and 23 is output to PWM waveform forming circuit 24, 25 or 26, respectively. Each of PWM waveform forming circuits 24, 25 and 26 forms a PWM waveform corresponding to the duty ratio data in 25 synchronization with a clock signal CLK.

PWM waveform forming circuit 24, 25 or 26 outputs a PWM waveform to the base of transistor 27, 28 or 29

based on the red-LED emission timing signal TR, green-LED emission timing signal TG, or blue-LED emission timing signal TB, respectively. In each of transistors 27, 28 and 29, the collector is connected to an output terminal 5 of the LED of R, G or B, while the emitter is grounded, respectively.

By this means, during an emission period of the red LED, only the red-LED emission timing signal TR has a logic value of "1", a PWM signal is only output from PWM waveform forming circuit 24 provided for the red LED, the current corresponding to the PWM signal flows into the red LED, and the red LED emits light. Similarly, during an emission period of the green LED, only the green-LED emission timing signal TG has a logic value 10 of "1", a PWM signal is only output from PWM waveform forming circuit 25 provided for the green LED, the current corresponding to the PWM signal flows into the green LED, and the green LED emits light. During an emission period of the blue LED, only the blue-LED emission timing signal 15 TB has a logic value of "1", a PWM signal is only output from PWM waveform forming circuit 26 provided for the blue LED, the current corresponding to the PWM signal flows into the blue LED, and the blue LED emits light.

FIG.3 illustrates a configuration of driving 25 voltage setting device 30 for setting voltage values to store in applied voltage storage registers 11, 12 and 13 for respective colors. In addition, driving voltage

setting device 30 has the configuration capable of obtaining duty ratio data for the LED of each color to store in duty ratio storage register 21, 22 or 23, as well as voltage values for the LED of each color to store 5 in applied voltage storage register 11, 12 or 13.

Driving voltage setting device 30 has luminance/chromaticity meter 31 to measure the luminance and chromaticity of transmission light from the LCD panel. In addition, the light emitted from LED unit 20 is incident 10 on luminance/chromaticity meter 31 via a light guide plate (not shown) and LCD panel 40. The predetermined voltage is applied to the liquid crystal at each pixel position from an LCD driving circuit (not shown) at predetermined timing to drive the liquid crystal in open or close, 15 whereby LCD panel 40 passes or shields the light emitted from the LED. In addition, it is assumed that LED unit 20, the light guide plate and LCD panel 40 are assembled in the same way as in shipment of the product.

The data of luminance and chromaticity obtained from 20 luminance/chromaticity meter 31 is output to microcomputer 32. Driving voltage setting device 30 has applied voltage setting section 33 and duty ratio setting section 34, and a voltage value set in applied voltage setting section 33 is output to DA converting circuit 25 17 of LED driving device 10, while the duty ratio data set in duty ratio setting section 34 is output to PWM waveform forming circuits 24, 25 and 26. The set voltage

value and set duty ratio are designated from microcomputer 32. In other words, the microcomputer recognizes the set voltage value and duty ratio.

Microcomputer 32 judges whether the luminance and 5 chromaticity meet respective desired values beforehand set, and when the desired values are met, writes the voltage value applied at this point in applied voltage storage register 11, 12 or 13, and further writes the duty ratio in duty ratio storage register 21, 22 or 23, 10 via storage value setting bus 14. In other words, microcomputer 32 has the function as means for writing storage data in applied voltage storage registers 11, 12 and 13 and in duty ratio storage registers 21, 22 and 23.

15 Referring to FIG.4, processing will specifically be described below for driving voltage setting device 30 to record applied voltage values (minimum emission voltages) in applied voltage storage registers 11, 12 and 13 for respective colors and further record the duty 20 ratio data in duty ratio storage registers 21, 22 and 23.

Driving voltage setting device 30 starts the processing in step ST10, and in the subsequent step, ST11, sets duty ratios in duty ratio setting section 34. Since 25 the case of FIG.4 shows processing for setting a voltage to apply to the red LED, the setting device 30 sets the ON duty ratio of the red LED at a maximum value, while

setting ON duty ratios of the green and blue LEDs at zero. In other words, PWM waveform forming circuit 24 is given data with the ON duty ratio of the maximum value, while PWM waveform forming circuits 25 and 26 are given data 5 with the ON duty ratio of "0". In step ST12, microcomputer 32 sets a target luminance.

In step ST13, applied voltage setting section 33 sets a minimum applied voltage value  $V_{min}$  (for example, 1.5V), and voltage varying circuit 18 converts the voltage 10 generated in power supply voltage generating circuit 19 into the set voltage to apply to LED unit 20. At this point, since only the red PWM waveform forming circuit 24 outputs a PWM signal with the maximum ON duty ratio, the red LED is only in a state for enabling light emission.

15 In step ST14, microcomputer 32 judges whether or not the measured luminance obtained by luminance/chromaticity meter 31 is greater than the target luminance. When the measured luminance is less than the target luminance, microcomputer 32 shifts to 20 the processing of step ST15, increases a set applied voltage in applied voltage setting section 33 by  $k$  (for example, 0.1V), and makes the judgment in step ST14 again.

A positive result obtained in step ST14 means that 25 the minimum voltage required to obtain a desired luminance is currently being applied to the red LED, and the processing flow shifts to step ST16 where microcomputer 32 writes the voltage value currently set in applied

voltage setting section 33 in R applied voltage storage register 11. Thus, the minimum emission voltage value required for the red LED to obtain a desired luminance is stored in R applied voltage storage register 11.

5        In the subsequent step, ST17, microcomputer 32 judges whether or not the measured luminance agrees with the target luminance. When agreement is not obtained, microcomputer 32 shifts to step ST18, decreases the ON duty ratio set in duty ratio setting section 32 by  $r$ ,  
10 and returns to step ST17.

A positive result obtained in step ST17 means that it is possible to cause the red LED to emit light with the desired luminance using the PWM signal with the duty ratio currently set in duty ratio setting section 34,  
15 and the processing flow shifts to step ST19 where microcomputer 32 writes the duty ratio currently set in duty ratio setting section 34 in R duty ratio storage register 21. Thus, the duty ratio for the red LED to obtain the desired luminance is stored in R duty ratio  
20 storage register 21.

In other words, the processing of steps ST17 to ST19 indicates that the duty ratio is set to perform fine luminance control using the PWM signal so as to bring the luminance close to the target luminance after setting  
25 in steps ST14 to ST16 the minimum applied voltage enabling the target luminance to be obtained. In the subsequent step, ST20, driving voltage setting device 30 finishes

the processing for writing data in R applied voltage storage register 11 and R duty ratio storage register 21.

In addition, herein described is the processing for 5 writing data in R applied voltage storage register 11 and R duty ratio storage register 21, and similar procedures are carried out to perform processing for writing data in G and B applied voltage storage registers 12 and 13 and G and B duty ratio storage registers 22 10 and 23.

Referring to FIG.5, procedures will be described below to store in the registers 21, 22 and 23 duty ratios for respective colors to obtain the desired white balance.

Driving voltage setting device 30 starts white 15 balance adjustment processing in step ST30, and in the subsequent step, ST31, lights the LEDs of respective colors sequentially using applied voltages stored in applied voltage storage registers 11, 12 and 13 and PWM signals with duty ratios stored in duty ratio storage 20 registers 21, 22 and 23, while driving LCD panel 40 using the LCD driving circuit (not shown).

Actually, LED driving device 10 applies voltages for the LEDs of respective colors stored in applied voltage storage registers 11, 12 and 13 sequentially to LED unit 25 20, and in synchronization with the voltage application, PWM waveform forming circuits 24, 25 and 26 form PWM signals for the LEDs of respective colors corresponding

to the duty ratios stored in duty ratio storage registers 21, 22 and 23.

In other words, in step ST31 is performed actual LED driving and LCD driving in the field sequential system.

5 It is herein assumed that data stored in applied voltage storage registers 11, 12 and 13 and duty ratio storage registers 21, 22 and 23 is data set as shown in FIG.4.

In step S32, luminance/chromaticity meter 31 measures the chromaticity of a display color. FIG.6 10 shows measured degrees of chromaticity plotted in the chromaticity space. Then, microcomputer 32 calculates a difference between the measured chromaticity and a target value of the white balance, and duty ratio setting section 34 corrects duty ratios to set corresponding to 15 the difference to supply to PWM waveform forming circuits 24, 25 and 26. Microcomputer 32 is capable of reading out duty ratios for respective colors stored in duty ratio storage registers 21, 22 and 23, and based on the read 20 duty ratios for respective colors and the difference between the measured chromaticity and target value of the white balance, designates the duty ratios for respective colors to next set in duty ratio setting section 34. By this means, the duty ratios for respective colors are set at values such that the target white balance is 25 obtained.

Specifically, it is first judged in step ST33 whether or not the Y coordinate of the measured chromaticity is

within a white allowable range as shown in FIG.6, and it is further judged in step ST34 whether or not the X coordinate of the measured chromaticity is within the white allowable range as shown in FIG.6. When a negative 5 result is obtained in either step ST33 or step ST34, the processing flow shifts to step ST35, and duty ratio setting section 34 corrects the duty ratio.

The correction of the duty ratio is made based on the difference in direction and scale between a target 10 point of the white balance and the measured chromaticity. In the case of this embodiment, microcomputer 32 considers a distribution range of chromaticity of the LED of each color, and corrects the duty ratio of the PWM signal for the LED of each color. For example, the amount of the 15 difference is allocated in proportion to the amount of correction of the duty ratio for the LED of each color in consideration of the distribution range of chromaticity of the LED of each color, whereby it is possible to find the duty ratio such that the white balance 20 falls within the allowable range promptly in a small number of corrections.

For example, as shown in FIG.6, a case is considered where the Y coordinate of a measured value is larger than that of the target point, and that the X coordinate of 25 the measured value is smaller than that of the target point. Respective distribution ranges of the LEDs of colors, R, G and B, in chromaticity space are generally

as shown in FIG.6. Therefore, in order to decrease the Y component and increase the X component to bring the white balance close to the target point, for example, the red ON duty ratio is increased, while the green ON 5 duty ratio is decreased.

By thus setting ON duty ratios in proportional allocation as described below, it is possible to find respective duty ratios for the colors such that the target white balance is obtained a small number of settings.

10       Obtaining positive results in both steps ST33 and ST34 mean that the white balance is in the white allowable range, and therefore, driving voltage setting device 30 shifts to step ST36, stores duty ratios for red, green and blue currently set in duty ratio setting section 34 15 respectively in duty ratio storage registers 21, 22 and 23, and finishes the white balance adjustment processing in the subsequent step, ST37.

Thus, driving voltage setting device 30 starts with the duty ratio such that a desired luminance is obtained 20 on the LED of each of colors, R, G and B, independently, measures the white balance of the actual display color, corrects respective duty ratios for the colors corresponding to the measured values, while searching 25 for duty ratios such that the desired white balance is obtained, and stores respective duty ratios for the colors at the time the desired white balance is obtained in corresponding duty ratio storage registers 21, 22 and

23.

In this way, driving voltage setting device 30 corrects the duty ratio for each color, thereby makes an adjustment to the white balance, and therefore, is 5 capable of adjusting the white balance finely with ease. Further, by storing duty ratios to adjust the white balance in writable registers 21, 22 and 23, it is possible to write duty ratios specific to each product while actually measuring the chromaticity of the product. Therefore, 10 even when there are fluctuations in LED, light guide plate and LCD panel for each product, it is possible to obtain the desired white balance in each product.

The operation of LED driving device 10 of this embodiment will be described below with reference to FIG. 7. 15 In LED driving device 10, in an red-LED emission period LR, register selecting circuit 15 first selects an output of R applied voltage storage register 11 among from outputs of applied voltage storage registers 11, 12 and 13, and voltage varying circuit 18 forms a voltage of 2.2V 20 corresponding to the output of R applied voltage storage register 11, and supplies the voltage of 2.2V to LED unit 20 as shown in FIG. 7(a).

When the red-LED emission timing signal TR rises at time  $t_2$  during the red-LED emission period LR, PWM 25 waveform forming circuit 24 outputs a PWM signal with the duty ratio stored in R duty ratio storage register 21 to transistor 27, and thereby the red LED emits light

in the luminance corresponding to the PWM signal. Then, when the red-LED emission timing signal TR falls at time t3, the output from PWM waveform forming circuit 24 is halted, and register selecting circuit 15 selects an 5 output of G applied voltage storage register 12, substituting for the output of R applied voltage storage register 11.

By this means, in a green-LED emission period LG, LED driving device 10 forms a voltage of 3.3V in voltage 10 varying circuit 18 corresponding to data of G applied voltage storage register 12, and supplies the voltage of 3.3V to LED unit 20. When the green-LED emission timing signal TG rises at time t4 during the green-LED emission period LG, PWM waveform forming circuit 25 outputs a PWM 15 signal with the duty ratio stored in G duty ratio storage register 22 to transistor 28, and thereby the green LED emits light in the luminance corresponding to the PWM signal. Then, when the green-LED emission timing signal TG falls at time t5, the output from PWM waveform forming 20 circuit 25 is halted, and register selecting circuit 15 selects an output of B applied voltage storage register 13, substituting for the output of G applied voltage storage register 12.

By this means, in a blue-LED emission period LB, 25 LED driving device 10 forms a voltage of 3.4V in voltage varying circuit 18 corresponding to data of B applied voltage storage register 13, and supplies the voltage

of 3.4V to LED unit 20. When the blue-LED emission timing signal TB rises at time t6 during the blue-LED emission period LB, PWM waveform forming circuit 26 outputs a PWM signal with the duty ratio stored in B duty ratio storage 5 register 23 to transistor 29, and thereby the blue LED emits light in the luminance corresponding to the PWM signal. Then, when the blue-LED emission timing signal TB falls at time t7, the output from PWM waveform forming circuit 26 is halted, and register selecting circuit 15 10 selects an output of R applied voltage storage register 11, substituting for the output of B applied voltage storage register 13.

Thereafter, in the same way as the foregoing, repeated are the red-LED emission period LR, green-LED 15 emission period LG and blue-LED emission period LB, whereby color display is carried out in the field sequential system.

In addition, in the case of this embodiment, each of the LED emission periods LR, LG and LB is set at about 20 5mS, and the PWM signal output period for each color is set at about 2000 $\mu$ s. Further, a waveform of the PWM signal has a unit cycle of 50 $\mu$ s, and the duty ratio in the unit cycle is stored in each of the duty ratio storage registers 21 to 23. In the case of this embodiment, duty 25 ratios of eight bits (=256 different ratios) are stored in each of the duty ratio storage registers 21 to 23.

Thus, according to this embodiment, the LED of each

of colors, red, green and blue, undergoes PWM control independently during a unit emission period to emit light, luminance/chromaticity meter 31 measures the chromaticity of the light emission, a difference is 5 calculated between the measured value and target white balance value, the duty ratio for the LED of each of the colors is corrected corresponding to the difference to light the LED of each of the colors again, and the duty ratio for the LED of each of the colors such that the 10 difference falls within a predetermined allowable range is stored in the duty ratio storage register 21, 22 or 23. It is thus possible to implement an adjustment method of a display device and the display device capable of making a white balance adjustment readily and finely even 15 when there are fluctuations in emission characteristics of LED and LCD panel 40.

Further, rough luminance adjustment is first made by storing a minimum voltage value for each color when a luminance higher than a target is obtained in a state 20 where the duty ratio is maximum, and fine luminance adjustment is then made by varying the duty ratio of the PWM signal while applying the stored applied voltage of fixed value, whereby current consumption can be reduced, in addition to the fact that white balance is adjusted 25 with excellence.

In addition, in the aforementioned embodiment, for simplicity in drawings and descriptions, LED unit 20 is

comprised of two red LEDs, two blue LEDs and one green LED, but the present invention is not limited to such the number of the LED of each color. Further, any number is available as the number of LED units 20, and it may 5 be possible to set the driving voltage and duty ratio of an LED of each color independently for each of the LED units to store in memory.

Moreover, it may be possible that a variable voltage is applied independently to each of LEDs of the same color, 10 the luminance is detected independently on each of LEDs of the same color, a minimum applied voltage value when a luminance higher than a desired value is detected is set as a driving voltage value on each of LEDs of the same color and stored in applied voltage storage register 15 11, 12 or 13, and that each of LEDs is driven with the voltage value. In this way, even when there are fluctuations in driving voltage required to obtain the desired luminance between LEDs of the same color, it is possible to drive each of the LEDs of the same color with 20 the minimum driving voltage corresponding to the fluctuations, and thus, current consumption can further be reduced.

Similarly, it may be possible that each of LEDs of the same color is controlled using the PWM signal with 25 a different duty ratio, the duty ratio for each of the LEDs of the same color when a desired luminance and white balance is detected is stored independently in duty ratio

storage register 21, 22 or 23, and that each of the LEDs undergoes PWM control using the duty ratio. In this way, even when there are fluctuations in duty ratio required to obtain the desired luminance and white balance between 5 LEDs of the same color, each of the LEDs can be controlled in PWM using the duty ratio corresponding to the fluctuations, and it is thereby possible to make a finer luminance adjustment and white balance adjustment.

Further, the above-mentioned embodiment describes 10 the case of using a liquid crystal display device in the field sequential system, but the present invention is not limited to such a case and widely applied to display devices to perform color display using LEDs of three colors, R, G and B. Furthermore, the above-mentioned embodiment 15 describes the case of applying the independent voltage for each color to an LED of each color, but the present invention is not limited to such a case and enables the same effects to be obtained also in the case of applying the same voltage to the LED of each color.

20 The present invention is not limited to the above-mentioned embodiment, and is capable of being carried into practice with various modifications thereof.

An aspect of an adjustment method of a display device 25 of the present invention includes an LED emission step of performing PWM control independently on an LED of each of colors, red, green and blue, in a unit emission period to cause the LED to emit light, a measuring step of

measuring chromaticity of the light, a calculating step of calculating a difference between a measured value obtained in the measuring step and a target white balance value, a correcting step of correcting a duty ratio of 5 a PWM signal on the LED of each of colors in the LED emission step corresponding to the difference obtained in the calculating step, and a duty ratio storing step of storing a duty ratio for the LED of each of colors in a storage when the difference calculated in the calculating step 10 falls within a predetermined allowable range.

According to this method, emission in a unit emission period of the LED of each of colors is controlled using the PWM signal, while storing in the storage the duty ratio of the PWM signal for the LED of each of colors 15 such that the white balance falls within an allowable range. Therefore, even when there are fluctuations between LEDs of the colors due to individual differences, it is possible to make a display adjustment with ease such that the white balance falls within an allowable 20 range.

In another aspect of the adjustment method of a display device of the present invention, the adjustment of the display device is made in such a state that an LCD panel is attached to a front face of the LED and that 25 the LCD panel is driven.

According to this method, even when there are fluctuations between LCD panels due to individual product

differences, it is possible to absorb the fluctuations and bring the white balance into an allowable range.

In still another aspect of the adjustment method of a display device of the present invention, in the 5 correcting step, the duty ratio of the PWM signal for the LED of each of colors is corrected in consideration of a distribution range of the chromaticity of the LED of each of colors.

According to this method, it is possible to find 10 the duty ratio such that the white balance falls within the allowable range promptly in a small number of corrections. For example, the amount of the difference is allocated in proportion to the amount of correction of the duty ratio for the LED of each of colors in 15 consideration of the distribution range of the chromaticity of the LED of each of colors.

In still another aspect of the adjustment method of a display device of the present invention, the duty ratio is corrected independently on LEDs of the same color 20 corresponding to the difference obtained in the calculating step, and independent duty ratios for the LEDs of the same color are stored in the duty ratio storing step.

According to this method, it is possible to adjust 25 the LEDs of the same color using independent PWM signals, and it is thereby possible to execute finer white balance adjustment processing than in the case of performing PWM

control on the LEDs of the same color collectively using the same PWM signal.

An aspect of a display device of the present invention adopts a configuration having a duty ratio storage which is comprised of writable memory and stores therein a duty ratio to perform PWM control independently on an LED of each of colors, red, green and blue, in a unit emission period, independently for each LED, a PWM controller which forms a PWM signal based on the duty ratio stored in the duty ratio storage independently for each LED to perform PWM control independently on the LED of each of colors in the unit emission period, and a signal line connected to the duty ratio storage to input the duty ratio to the duty ratio storage.

Another aspect of the display device of the present invention adopts a configuration where the duty ratio storage stores the duty ratio provided with a white balance adjustment via the signal line.

According to these configurations, emission in a unit emission period of the LED of each of colors is controlled using the PWM signal, and it is thereby possible to adjust the white balance finely with ease. Further, the duty ratio of the PWM signal for the LED of each of colors is stored in the writable memory, and it is thus possible to write the duty ratio adapted to the display device at any time.

Still another aspect of the display device of the

present invention adopts a configuration where the duty ratio storage stores independent duty ratios for LEDs of the same color, and the PWM controller forms independent PWM signals for the LEDs of the same color to perform 5 PWM control independently on the LEDs of the same color in a unit emission control.

According to this configuration, the LEDs of the same color are also controlled in emission using the independent PWM signals, and it is thus possible to perform 10 finer white balance display.

As described above, according to the present invention, emission in a unit emission period of the LED of each of colors is controlled using the PWM signal, while storing in the storage the duty ratio of the PWM 15 signal for the LED of each of colors such that the white balance falls within an allowable range. Therefore, it is possible to implement an adjustment method of a display device and the display device enabling the white balance adjustment to be made finely with ease even when there 20 are fluctuations in emission characteristics of LED and LCD panel.

Further, rough luminance adjustment is first made by storing a minimum voltage value for each color when a luminance higher than a target is obtained in a state 25 where the duty ratio is maximum, and fine luminance adjustment is then made by varying the duty ratio of the PWM signal while applying the stored applied voltage of

fixed value, whereby current consumption can be reduced, in addition to the fact that the white balance is adjusted with excellence.

This application is based on the Japanese Patent 5 Application No. 2003-98488 filed on April 1, 2003, entire content of which is expressly incorporated by reference herein.

#### Industrial Applicability

10 The present invention is suitable for being applied to, for example, a liquid crystal display device.